

### Listed or Labeled Equipment

Listed or labeled equipment must be installed in accordance with instructions included in the listing or labeling [110.3(B)]. Be sure to observe maximum branch circuit fuse size labels. When the equipment label is marked with a maximum fuse amp rating rather than marked with maximum overcurrent device amp rating, only fuses can be used for protection of this equipment.

### Panelboards

A maximum of 42 fuses (excluding main fuses) are permitted to be installed in a lighting and appliance branch circuit panelboard (408.35). Each lighting and appliance branch circuit panelboard must be individually protected on the supply side by not more than two sets of fuses having a combined rating not greater than that of the panelboard (408.36). Exception No. 1: Individual protection is not required when the panelboard feeder has overcurrent protection not greater than that of the panelboard. Exception No. 2: Individual protection in existing installations is not required for individual residential occupancy service entrance panelboards [408.36(A)]. A power panelboard having supply conductors which include a neutral and having more than 10% of its overcurrent devices protecting branch circuits of 30A or less, shall have individual protection on the line side not greater than the rating of the panelboard. Individual protection is not required when the power panel is used as service equipment in accordance with 230.71 [408.36(B)]. Panels with snap switches rated at 30A or less must be protected by fuses not larger than 200A [408.36(C)]. Fusible panelboards are available with heavy duty toggle switches rated more than 30A; these panelboards are not restricted by this 200A requirement.

If the panelboard is supplied through a transformer, the fuses for the protection of the panelboard must be located on the transformer secondary [408.36(D)] except when the fuse on the primary complies with 240.2(C)(1). [408.36(D) Exception].

### **Appliances**

Appliance branch circuits shall be protected in accordance with 240.5. If a fuse rating is marked on an appliance, the branch circuit fuse rating cannot exceed that rating marked on the appliance [422.11(A)]. See 430.6(A)(1) exception No.3 for situations where the appliance is marked with both a horsepower rating and an amp rating.

For branch circuits which supply a single non-motor operated appliance rated more than 13.3A, the fuse rating shall not exceed 150% of the appliance rating [422.11(E)(3)].

Electric heating appliances using resistance heating elements rated more than 48A shall have the heating elements subdivided such that each subdivision does not exceed 48 amps and each subdivision shall be protected by a branch circuit listed fuse not to exceed 60A in rating. These fuses shall be factory installed by the heater manufacturer, be accessible, and be suitable for branch circuit protection [422.11(F)(1)].

Fixed appliances are considered protected when supplied from 15, 20, 25, or 30A branch circuits. Fixed cooking appliances are permitted to be protected by 40 or 50A branch circuits (210.23). Household appliances with surface heating elements that have a maximum rating greater than 60A must be divided into two or more circuits, each of which is protected by a fuse of no greater than 50A [422.11(B)].

Portable appliances are considered as protected when supplied from a 15, 20A, or 30A branch circuit (210-23).

### **Supplementary Protection**

Supplementary overcurrent protection is permitted by the National Electrical  $Code^{@}$  for specific uses such as in lighting fixtures, appliances, and other

equipment or for certain internal control circuits and components of equipment. This type of protection must not be used as a substitute for branch circuit protection as described in Article 210. This type of protection is not required to be readily accessible as are branch circuit devices. There are a wide variety of supplementary fuses and fuse holders, which have small physical dimensions and are easily installed in or on equipment, appliances, or fixtures. The advantages of supplementary protection are closer fuse sizing for better individual protection, isolation of equipment on overcurrents so that the branch circuit fuse is not disturbed, ease in locating troubled equipment, and generally direct access to the fuse at the location of the equipment. For instance, the inline fuse and holder combination, such as the Type HLR fuse holder with Type GLR or GMF fuses, protects and isolates fluorescent lighting fixtures in the event of an overcurrent.

The Tri-National Standard for supplementary fuses is UL/CSA/ANCE 248-14. When supplementary overcurrent protective devices are considered for proper use, it is important (1) not to use these devices as a substitute for branch circuit protection and (2) to be sure that the device's interrupting rating equals or exceeds the available short-circuit current (see the discussion for 110.9 in this booklet).

# Air Conditioning and Refrigeration

Air conditioning and refrigeration equipment requirements are covered in Article 440 of the National Electrical Code<sup>®</sup>. Hermetic motor-compressors are not rated in "full-load amps" as are standard motors. Instead, different terms are used, such as rated load current, branch circuit selection current, maximum continuous current, minimum circuit ampacity, and maximum overcurrent protection. This equipment has overcurrent protection requirements that differ from that for ordinary motors covered in Article 430. Some highlights are presented here.

### **Branch Circuit Protection HVAC**

### Individual Motor-Compressor(s) and HVAC Equipment Having Motor-Compressor(s) and Other Loads (Such as Fan Motors, Electric Heaters, Coils, etc.).

Fuses sized for branch circuit protection only must not exceed 175% of the hermetic motor-compressor rated-load current or branch circuit selection current (whichever is larger). If this size fuse cannot withstand the motor starting current, a higher amp rating is permitted, but in no case can the fuse size exceed 225% [440.22(A)].

Low-Peak dual-element and Fusetron dual-element fuses are recommended for branch circuit protection of air conditioning and refrigeration hermetic motorcompressors because these fuses have an adequate time-delay for motor starting surges.

Refer to the nameplate on the equipment. The sizing (amp rating) for the overcurrent protection has been determined by the manufacturer of the equipment. It is not necessary to apply any further multipliers to arrive at the proper size. This has already been done by the manufacturer.

The marked protective device rating is the maximum protective device rating for which the equipment has been investigated and found acceptable by nationally recognized testing laboratories.

See "Listed or Labeled Equipment" for requirement when nameplate states Maximum Size Fuse. This is a critical requirement, and must be followed without exception to be in compliance with 110.3(B) of the Code. NEC<sup>®</sup> 110.3(B) requires that listed or labeled equipment must be installed in accordance with any instructions included in the listing or labeling.



### **Disconnecting Means**

### (Individual hermetic motor compressor)

The amp rating of the disconnect shall be at least 115% of the compressors rated load current or branch-circuit selection current, whichever is greater [440.12(A)(1)]. 440.12(A)(1) Exception permits a nonfused disconnect rated less than 115% of the specified current if this disconnect has a horsepower rating not less than the equivalent horsepower rating per 440.12(A)(2).

The equivalent horsepower rating to comply with 430.109 can be obtained by taking the larger horsepower value from: (1) NEC<sup>®</sup> Tables 430.248. 430.249 or 430.250 using the greater of either the rated load current or the branch circuit selection current to select the corresponding horsepower rating, or (2) horsepower rating from Tables 430.251(A) and 430.251(B) corresponding to the locked-rotor current. For both preceding (1) and (2), if the value falls between two horsepower ratings in a table, the equivalent horsepower rating to use is the larger of the two; i.e. round up to the larger HP. [440.12(A)(2)].

# **Disconnecting Means** (Equipment that has hermetic motor-compressor and other loads)

The amp rating of the disconnecting means must be at least 115% of the sum of all of the individual loads within the equipment at rated load conditions [440.12(B)(2)]. 440.12(B)(2) Exception permits a nonfused disconnect rated less than 115% of the sum of all the individual loads if the disconnect has a horsepower rating not less than the equivalent horsepower rating per 440.12(B)(1).

The horsepower rating of the disconnecting means must be at least equal to the equivalent horsepower determined per 440.12(B)(1) which accounts for all the individual loads with the equipment at rated load conditions.

### Controller

The controller for a hermetic motor-compressor must have a continuous duty full-load current rating not less than the nameplate rated current or branch circuit selection current (whichever is larger) (440.41) and the controller must also have a locked rotor current rating equal to or greater than the locked rotor current of the compressor [440.41(A)]. Where the controller serves a hermetic motor-compressor(s) plus other loads, the controller rating is determined according to 440.12(B), in much the same manner as determining the disconnecting means rating. It may be necessary to refer to Tables 430.251(A) & (B) to convert locked rotor current values to horsepower.

The branch circuit protective device rating shall not exceed the maximum protective device rating shown on a manufacturer's heater table for use with a given motor controller [440.22(C)]. Where the equipment is marked Maximum Size Fuse amp rating rather than stating Maximum Overcurrent Device amp rating, only fuses can be used for the branch circuit protection.

### Marked Short-Circuit Current Rating - New Air Conditioning and Refrigeration Equipment with Multimotor and Combination-Loads

440.4(B) requires the nameplate of this equipment to be marked with its shortcircuit current rating. There are exceptions for which this requirement does not apply to this equipment:

- One and two family dwellings
- · Cord and attachment-plug connected equipment
- Or equipment on a 60A or less branch circuit

So for most commercial and industrial applications, air conditioning and refrigeration equipment with multimotor and combination loads must have the short-circuit current rating marked on the nameplate. This facilitates the inspection and approval process. Inspectors need this information to ensure

that NEC<sup>®</sup> 110.10 is met. A potential hazard exists where the available shortcircuit current exceeds the short-circuit current rating. For more information, see the Assembly Short-Circuit Current Rating section in this publication or Short-Circuit Current Rating web page on <u>www.cooperbussmann.com</u>.

### **Room Air Conditioners**

Room air conditioners (hermetic refrigerant motor-compressor) installed in the conditioned room are considered as single-motor units when the conditions of 440.62 are met. This condition also applies to conditioners containing a heating unit. Branch circuit requirements are determined by nameplate rating (440.62).



Because of all the fires caused by mistreated cords, single phase cord-andplug connected room air conditioners are now required to have either an AFCI (arc fault circuit interrupter) or a LCDI (leakage current detection and interruption) attached to the plug.

### **Electric Heat**

Electric space heating equipment employing resistance type heating elements, rated more than 48A, must have heating elements subdivided. Each subdivided load must not exceed 48A, and the fuse for each load should not exceed 60A [424.22(B)]. If a subdivided load is less than 48A, the fuse rating should be 125% of that load.

Exception: Boilers employing resistance type immersion electric heating elements in an ASME rated and stamped vessel may be subdivided into circuits not exceeding 120A, and protected by a fuse at not more than 150A [424.22(B) and 424.72(A)]. If a subdivided load is less than 120A, the fuse rating should be 125% of that load.

Fusetron dual-element fuses in the sizes required above provide protection for electric heat applications (their lower internal resistance offers cooler operation than ordinary fuses).

T-Tron fast-acting fuses (JJN and JJS) in the sizes required above provide protection for electric heat applications and offer small physical size to reduce space and material cost.

### Capacitors

The purpose of fusing capacitors is for short circuit protection. When a capacitor fails, it shorts out. Proper fusing is intended to remove the shorted capacitor from the circuit, prevent the shorted capacitor from rupturing and protect the conductors from damage due to short-circuit current. However, proper fusing must also be sized such that the capacitor can operate normally; that is the fuse should not open due to the normal steady state current or the inrush current when voltage is applied. For example, when the circuit is switched on, a capacitor in the circuit can draw a very high inrush current for a very brief time. Therefore, a capacitor fuse must have the characteristics to not open due to the initial inrush current. Also, the steady state current of a capacitor is directly proportional to the applied voltage; when the voltage increases the capacitor current increases.



A fuse must be provided in each ungrounded conductor (no protection is required for a capacitor connected on the load-side of a motor running overcurrent device). The fuse rating must be as low as practical [460.8(B)]. Generally, size dual-element, current-limiting fuses at 150% to 175% of the capacitor rated current and size non-time-delay, fast-acting, current-limiting fuses at 250% to 300% of the capacitor rated current.

Conductor ampacity must be at least 135% of the capacitor rated current [460.8(A)]. The ampacity of conductors for a capacitor connected to a motor circuit must be  $\frac{1}{2}$  the ampacity of the motor circuit conductors [460.8(A)].

### Welders

**Arc Welders** must be protected by a fuse rated at not more than 200% of the rated primary current. The fuse protecting the supply conductor can serve as the welder protection, if the fuse is rated at not more than 200% of  $I_{1max}$  or the welder rated primary current [630.12(A)]. Conductors supplying one or more welders must be protected by a fuse rated at not more than 200% of the conductor rating [630.12(B)].

**Resistance Welders** must be protected by a fuse rated at not more than 300% of the rated primary current of the welder. The fuse protecting the supply conductor can serve as the welder protection if the fuse is rated at not more than 200% of the welder rated primary current [630.32(A)]. Conductors supplying one or more welders must be protected by a fuse rated at not more than 300% of the conductor rating [630.32(B)].

For arc welder and resistance welder protection, Fusetron and Low-Peak dualelement fuses can be sized much closer than the above limits of 200% and 300%, respectively. Generally, the amp rating of these dual-element fuses can be sized at 100% of the conductor ampacity as determined according to the respective duty cycle multipliers found in 630.11(A), and 630.31(A)(2). As an example, for a resistance welder rated on a 50% duty cycle, Fusetron or Low-Peak dual-element fuses can be sized at 71% of the welder rated primary current.

### Hazardous (Classified) Locations

The characteristics of various atmospheric mixtures of hazardous gases, vapors and dusts depend on the specific hazardous material involved. It is necessary therefore that equipment be approved not only for the class of location but also for the specific gas, vapor or dust that will be present (500.5). Class I, Divisions 1 and 2 [501.115(A) and 501.115(B)(3)] – Fuses may be used provided they are within enclosures approved for the purpose and location.

### **Class I Division 1**

Fuses located in Class 1 Division 1 locations are required to be provided with enclosures that are identified as a complete assembly for use in Class I locations [501.115(A)].

### Class I Division 2 Fuses In General Purpose Enclosures

Certain fuses are permitted to be used in general purpose enclosures. 501.115(B)(3) addresses the use of current-limiting fuses in Class I Division 2 locations. Plug and cartridge fuses used for the protection of motors, appliances, and lamps are permitted provided they are placed in enclosures rated for the location. Fuses are permitted in general-purpose enclosures if they meet one of the following criteria:

- a. They are the type which the element is immersed in oil or other approved liquid
- b. The element is hermetically sealed against gases and vapors
- c. They are non-indicating, filled, and current-limiting type

Cooper Bussmann offers many fuses that meet the criteria for non-indicating, filled, current-limiting type (check Data Sheet 8003 for any updates):

Class CC : LP-CC ½ - 30A, KTK-R ½ - 30 A, FNQ-R ½ - 30A

Class T: JJN 1 - 1200A, JJS 1 - 800A

Class J: JKS 1 - 600A, LPJ\_SP 1 - 600A

Class G: SC ½ - 60A

Class RK1: KTN-R 1 - 600A, KTS-R 1 - 600A, LPN-RK\_SP\* 3½ -6½ and 65 - 600A, LPS-RK\_SP\* 65 - 600A

Class RK5: FRN-R 3½ - 7½ and 450 - 600A, FRS-R\*\* 65 - 600A

Class L: KRP-C\_SP 601 - 6000A, KTU 601 - 6000A, KLU 601 - 4000A

\*Fuses from July 1996 or date code C28 to present only.

\*\*Fuses from October 1997 or date code D40 to present only

Class I, Division II — Listed cartridge fuses shall be permitted in luminaries (lighting fixtures) [501.115(B)(4)].

Class II, Division 1 — Fuses must be provided with enclosures approved for Class II locations [502.115(A)(1)].

Class II, Division 2 — Fuses must be provided with dust tight enclosures [502.115(B) and 502.135(B)(3)].

Class III, Fuses must be provided with dust tight enclosures (503.115).

### **Mobile Homes**

The branch circuit equipment may be combined with the disconnecting means as a single assembly. Such a combination may be designated as a distribution panel. Plug fuses must be Type S (550.11).

Branch circuit overcurrent devices must be rated [550.11(B)]:

- 1. Not more than the circuit conductors.
- 2. Not more than 150% of the rating of a single appliance rated 13.3A or more supplied by an individual branch circuit.
- 3. Not more than the fuse size marked on the air conditioner or other motor-operated appliance.

### Ballasts

Each light fixture ballast should be individually protected by fuses. Fusing each fixture provides protection and isolation of a faulted ballast. When a ballast does fail, only the fuse for that fixture opens, and the remaining fixtures continue in normal operation. Without this individual ballast protection, a faulted ballast could cause the branch circuit protective device to open, thereby blacking out all fixtures. Additionally, special integrally protected ballasts, known as Class P Ballasts, are UL Listed under a 200A short circuit test condition. This test is conducted utilizing a fuse as the branch protection. The starting current and continuous current characteristics for lighting ballast can vary considerably for various manufacturers. For proper fuse amp rating, observe ballast manufacturer's recommendation.

There is a wide variety of supplementary and branch circuit fuses available for protection of light fixture ballasts including fluorescent lighting, mercury vapor lighting, and sodium lighting, indoor and outdoor.

See additional information under Component Protection-Ballasts.



## Transformers — 600V or Less

The requirements of 450.3 cover only transformer protection. In practice, other components must be considered in applying circuit overcurrent protection. For circuits with transformers, requirements for conductor protection per Articles 240 and 310 and for panelboards per Article 408, must be observed. Refer to 240.4(F), 240.21(B)(3), 240.21(C), 408.36(A) & (B).

*Primary Fuse Protection Only* [450.3(B)] (See Figure below) If secondary fuse protection is not provided (as discussed in the next Section) then the primary fuses must not be sized larger than as shown below.

Individual transformer primary fuses are not necessary where the primary circuit fuse provides this protection.

Primary Fuse Only					
Primary Current	y Current Primary Fuse Rating				
9 amps or more	125% or next higher standard rating if				
	125% does not correspond to a standard fuse				
	size.				
2 amps to 9 amps	167% maximum				
Less than 2 amps	300% maximum				



Note: Section 450.3 requirements pertain only to transformer protection. Additional circuit overcurrent protection for conductors or panelboards may be required per Articles 240, 310, 408, 430.72.

\* Primary Fuse (600V or less) and Secondary Fuse (600V or less). If secondary (600V or less) fuses are sized not greater than 125% of transformer secondary current, individual transformer fuses are not required in the primary (600V or less) provided the primary feeder fuses are not larger than 250% of the transformer rated primary current. [See Note 3 of Table 450.3(B) for overcurrent protection requirements of thermally protected transformers].





**Note:** Transformer overload protection will be sacrificed by using overcurrent protective devices sized much greater than the transformer F.L.A. The limits of 150%, 167%, 250% and 300% may not adequately protect transformers. It is suggested that for the highest degree of transformer overload protection the fuse size should be within 125% of the transformer full-load amps.

Normal magnetizing inrush currents for power transformers can range from 10 times to 12 times the transformer full load current, for up to 6 cycles, and as high as 25 times transformer full load current at 0.01 seconds. Some

transformers may have inrush magnitudes substantially greater. Severe inrush should be compared with melting times to assure that unnecessary opening of the device does not occur.

There is a wide fuse amp rating range available to properly protect transformers. Fusetron Class RK5 and Low-Peak Class RK1 dual-element fuses can be sized on the transformer primary and/or secondary rated at 125% of the transformer F.L.A. These dual-element fuses have sufficient timedelay to withstand the high magnetizing inrush currents of transformers. There is a wide amp rating selection in the 0 to 15A range for these dual-element fuses to provide protection for even small control transformers.

The required secondary protection may be satisfied with multiple overcurrent devices that protect feeders fed from the transformer secondary. The total amp rating of these multiple devices may not exceed the allowed value of a single secondary overcurrent device. If this method is chosen, dual-element, time-delay fuse protection offers much greater flexibility. Note the following examples:



Design 1 utilizes a single secondary overcurrent device. It provides the greatest degree of selective coordination, transformer protection, secondary cable protection, and switchboard/ panelboard/load center protection. The transformer cannot be overloaded to a significant degree if future loads are added (improperly). With this arrangement the transformer's full capacity is utilized.



## Transformers — 600V or Less



**Design 2** In this case the single secondary overcurrent device is eliminated, much of the protection described in Design 1 will be reduced. If dual-element fuses are utilized as branch circuit protection, the transformer can continue to be loaded with the five 83A motors because  $5 \times 110 = 550A$ , (less than the maximum 600A). If additional loads are improperly added in the future, overload protection will be lost because the primary device can be sized at 250%.



Design 3 If the single secondary overcurrent device is eliminated and MCPs are utilized as branch circuit protection, the transformer will be seriously under-utilized because only one motor can be connected. For one motor, 1 x 700% of 83 = 581 amps. For two motors, 2 x 700% of 83 = 1162 amps. Since the sum of the devices cannot exceed 600 amps, only one motor can be connected when the motor circuit is protected by an MCP.



**Design 4** Using the same procedure, if the single secondary main is eliminated and thermal magnetic circuit breakers are utilized as branch circuit protection per 430.52, only three of the motors can be connected because the thermal magnetic breakers will have been sized at approximately 250% of the motor F.L.A. (83 x 250% = 207.5A.)

**Note:** If sized less than permitted by 430.52, nuisance tripping may result since the new energy efficient motors have higher inrush currents.

Using a 200A circuit breaker would allow only three ( $600 \div 200$ ) motors to be connected. To add two additional motors of the same type as shown in Design 1 and Design 2 requires a larger transformer - one that would have a 1000A or more secondary capability. A 300kVA 208V transformer has a 830A secondary rating which is not sufficient. Therefore, the next standard size 3Ø transformer is a 400kVA with a 1110A capacity to meet the new rule.



Transformers — Over 600V

### **Primary and Secondary Protection**

In unsupervised locations, with primary over 600V, the primary fuse can be sized at a maximum of 300%. If the secondary is also over600V, the secondary fuses can be sized at a maximum of 250% for transformers with impedances not greater than 6% or 225% for transformers with impedances greater than 6% and not more than 10%. If the secondary is 600V or below, the secondary fuses can be sized at a maximum of 125%. Where these ratings do not correspond to a standard fuse size, the next higher standard size is permitted.



In supervised locations, the maximum ratings are as shown in the next diagram. These are the same maximum settings as the unsupervised locations except for secondary voltages of 600V or less, where the secondary fuses can be sized at maximum of 250%.



### **Primary Protection Only**

In supervised locations, the primary fuses can be sized at a maximum of 250%, or the next larger standard size if 250% does not correspond to a standard fuse size.

**Note:** The use of "Primary Protection Only" does not remove the requirements for compliance with Articles 240 & 408. See (FPN) in Section 450.3, which references 240.4, 240.21, 240.100 and 240.101 for proper protection for secondary conductors.

### E-Rated Fuses for Medium Voltage Potential & Small Power Transformers

Low amperage, E-Rated medium voltage fuses are general purpose currentlimiting fuses. A general purpose current-limiting fuse is capable of interrupting all current from the rated interrupting current down to the current that causes melting of the fusible element in 1 hour (ANSI C37.40). The E rating defines the melting-time-current characteristic of the fuse and permits electrical interchangeability of fuses with the same E Rating. For a general purpose fuse to have an E Rating the following condition must be met:

The current responsive element shall melt in 300 seconds at an RMS current within the range of 200% to 240% of the continuous current rating of the fuse, fuse refill, or link (ANSI C37.46).

Cooper Bussmann low amperage, E-Rated fuses are designed to provide primary protection for potential, small service, and control transformers. These fuses offer a high level of fault current interruption in a self-contained nonventing package which can be mounted indoors or in an enclosure.

### Application

As for all current-limiting fuses, the basic application rules found in the fuseology section of this brochure should be adhered to. In addition, potential transformer fuses must have sufficient inrush capacity to successfully pass through the magnetizing inrush current of the transformer. If the fuse is not sized properly, it will open before the load is energized. The maximum magnetizing inrush currents to the transformer at system voltage, and the duration of this inrush current varies with the transformer design. Magnetizing inrush current, i.e., 10x, 12x, 15x, etc. The inrush current duration is usually given in seconds. Where this information is available, an easy check can be made on the appropriate Cooper Bussmann minimum melting curve to verify proper fuse selection. In lieu of transformer inrush data, the rule of thumb is to select a fuse size rated at 300% of the primary full-load current and round up to the next larger standard size.

### Example:

The transformer manufacturer states that an 800VA 2400V, single phase potential transformer has a magnetizing inrush current of 12x lasting for 0.1 second.

A. I<sub>FL</sub> = 800VA/2400V = 0.333A

Inrush Current = 12 x 0.333 = 4A

Since the voltage is 2400 volts we can use either a JCW-1E or JCD-1 E.

B. Using the rule of thumb-300% of 0.333A is 0.999A.

Therefore we would choose a JCW-1E or JCD-1E.



# Transformers — Over 600V

### **Typical Potential Transformer Connections**

The typical potential transformer connections encountered in industry can be grouped into two categories:



### E-Rated Fuses for Medium Voltage Transformers & Feeders

Cooper Bussmann E-Rated medium voltage fuses are general purpose current-limiting fuses. A general purpose current-limiting fuse is capable of interrupting all currents from the rated interrupted current down to the current that causes melting of the fusible element in 1 hour (ANSI C37.40). The fuses carry either an 'E' or an 'X' rating which defines the melting-time-current characteristic of the fuse. The ratings are used to allow electrical interchangeability among different manufacturers' fuses.

For a general purpose fuse to have an E rating, the following conditions must be met:

- 100E and below the fuse element must melt in 300 seconds at 200% to 240% of its rating (ANSI C37.46).
- Above 100E the fuse element must melt in 600 seconds at 220% to 264% of its rating (ANSI C37.46).



Cooper Bussmann E-Rated Medium Voltage Fuse.

A fuse with an 'X' rating does not meet the electrical inter-changeability for an 'E' rated fuse but offers the user other ratings that may provide better protection for a particular application.

### Application

Transformer protection is the most popular application of E-Rated fuses. The fuse is applied to the primary of the transformer and is used solely to prevent rupture of the transformer due to short circuits. It is important, therefore, to size the fuse so that it does not clear on system inrush or permissible overload currents. See section on transformers over 600V for applicable sizing recommendations. Magnetizing inrush must also be considered when sizing a fuse. In general, power transformers have a magnetizing inrush current of 12x the full-load rating for a duration of ½ second.

#### Three-Phase Transformers (Or Transformer Bank)

Transformer kVA Rating	Syste 2.4kV Full-lo Amps	m Voltage bad Fuse	e 4.16kV Full-load Fuse Amps		4.8kV Full-load Fuse Amps	
9	2.17	JCX-7E	1.25	JCY-5E	1.08	JCY-5E
15	3.6	JCX-10E	2.08	JCY-7E	1.8	JCY-7E
30	7.3	JCX-20E	4.2	JCY-15E	3.6	JCY-10E
45	10.8	JCX-25E	6.2	JCY-15E	5.4	JCY-15E
75	18.0	JCX-40E	10.4	JCY-25E	9.0	JCY-20E
112.5	27.0	JCX-65E	15.6	JCY-40E	13.5	JCY-30E
150	36.0	JCX-65E	20.8	JCY-40E	18.0	JCY-40E
225	54.0	JCX-100E	31.2	JCY-65E	27.0	JCY-65E
300	72.0	JCX-125E	41.6	JCY-80E	36.0	JCY-65E
500	120.0	JCX-200E	69.4	JCY-125E	60.0	JCY-100E
750	_	_	104.0	JCY-150E	90.0	JCY-125E
1000	_	_	139.0	JCY-200E	120.0	JCY-200E
Single-Pha	se Trans	formers				
3	1.25	JCX-5E	0.72	JCY-3E	0.63	JCY-3E
5	2.08	JCX-7E	1.20	JCY-5E	1.04	JCY-5E
10	4.17	JCX-15E	2.40	JCY-7E	2.08	JCY-7E
15	6.25	JCX-15E	3.61	JCY-10E	3.13	JCY-10E
25	10.4	JCX-25E	6.01	JCY-15E	5.21	JCY-15E
37.5	15.6	JCX-40E	9.01	JCY-20E	7.81	JCY-20E
50	20.8	JCX-40E	12.0	JCY-25E	10.4	JCY-25E
75	31.3	JXC-65E	18.0	JCY-40E	15.6	JCY-30E
100	41.7	JCX-80E	24.0	JCY-80E	20.8	JCY-40E
167	70.0	JCX-100E	40.0	JCY-100E	35.0	JCY-65E
250	104.0	JCX-150E	60.0	JCY-125E	52.0	JCY-100E
333	139.0	JCX-200E	80.0	JCY-125E	69.5	JCY-100E
500	_		120.0	JCY-200E	104.0	JCY-150E
667	_		_	—	139.0	JCY-200E

# **Protection**



# Photovoltaic (PV) Systems

A photovoltaic system is used to convert light energy from the sun to electrical energy for powering loads. These systems can power DC loads, or the output can be fed through an inverter to power AC loads. There are three basic types of solar photoelectric systems: stand-alone systems, interactive (grid-connected) systems, and hybrid systems. Stand-alone systems supply power independent of any other electrical power source. Interactive systems operate in parallel with another electrical power source such as being connected to an electrical utility system. An interactive system may also supply electric power to the production or distribution network. Hybrid systems include other power sources, such as wind and hydroelectric generation, in addition to solar photovoltaic sources.

Photovoltaic systems can be simple to complex. There can be many components such as photovoltaic panels, collector or combiner boxes, battery systems, charge controllers, and inverters. There are various overcurrent protection needs and requirements for different parts of the system. This section is not a comprehensive discussion of the various photovoltaic systems and all the requirement considerations.

The basic power-generating component of a solar photovoltaic system is the solar cell. In order to generate useful levels of power, groups of cells are combined to form modules. Modules are then grouped into panels, and several panels form a solar array. A photovoltaic power source can consist of one or more arrays. The short circuit current that can be delivered from a photovoltaic panel is only 110% to 115% of the operating current. This is quite different than the conventional AC system supplied by utility or on-site generators. However, parts of photovoltaic systems may have to withstand higher short-circuit current. Also, if the system is connected to the conventional electrical distribution system fed by a utility, fault current can be substantial.

Solar photovoltaic system installations are covered by NEC<sup>®</sup> Article 690. 690.2 defines the photovoltaic source circuit as "Circuits between modules and from modules to the common connection point(s) of the DC system." Figure 1 illustrates a simple photovoltaic source circuit.



### **All Overcurrent Protective Devices**

Per NEC<sup>®</sup> 690.9(A), the PV source circuit, PV output circuit, inverter output circuit, storage battery circuit conductors and equipment shall be protected per Article 240; this requires branch circuit fuses and circuit breakers (except for PV source circuits). Any fuse or circuit breaker used in the dc portion of the system must be listed for dc use. 690.9(D) requires all overcurrent devices to be listed for the dc voltage and dc interrupting rating equal to or greater than the required values.

Per 690.7(A), the required rated voltage for overcurrent protective devices and other components in the dc PV source and output circuits shall be based on rated open-circuit voltage corrected for expected ambient temperature. The open-circuit voltage is the sum the open-circuit voltage of the series connected PV modules and can be significantly greater than the closed circuit voltage. The voltage ambient temperature correction factors in NEC<sup>®</sup> Table 690.7 for crystalline and multicrystalline silicon modules is shown below:

Temperature	Correction Factor for Ambient less than		
°C	25°C/77°F		
25 to 10	1.06		
9 to 0	1.11		
-1 to -10	1.13		
-11 to -20	1.17		
-21 to -40	1.25		
	Temperature °C   25 to 10 9 to 0   -1 to -10 -11 to -20   -21 to -40 -21 to -40	Correction Factor for Ambient less than 25 to 10   25 to 10 1.06   9 to 0 1.11   -1 to -10 1.13   -11 to -20 1.17   -21 to -40 1.25	

If a fuse is energized from both directions and accessible by unqualified persons, then the disconnect means shall disconnect the fuse from all sources of supply (690.16).

### **Photovoltaic Source Circuits**

NEC<sup>®</sup> 690.9 allows supplementary, as well as branch circuit overcurrent protective devices, to be used in photovoltaic source circuits. If supplementary fuses are used, they must "be listed for use in dc circuits" and "have the appropriate voltage, current, and interrupt ratings" according to 690.9(D). Fuses such as the Cooper Bussmann DCM series can be in the dc PV source circuits. However, UL 1077 supplementary overcurrent protective devices are not UL Listed and therefore do not meet this requirement.



For more information on the DCM fuses and CHM holder, please visit www.cooperbussmann.com and download Data Sheet numbers 2038 and 2143.

Figure 1

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Figure 2 illustrates how DCM fuses in CHM holders are often used in the collector box. The DCM fuses protect the PV source circuit. Typically a PV source circuit operating current is 3 to 6 amps. A DCM 15 is installed for each PV source circuit. The DCM fuse is intended to open if the PV source circuit faults. When one PV source circuit faults all the other PV source circuits will back feed into the faulted PV source circuit. The DCM fuses melt. The DCM fuse on the faulted circuit opens before the other DCM fuses melt. Therefore, the other PV circuits can continue in normal operation.



• Purpose of these fuses is to have the fuse on the faulted circuit open, thus stopping current flowing to the faulted circuit from the other panels. Therefore, the other panels continue supplying power in a normal manner.

### Figure 2

### Battery Circuit Protection: Current-Limiting Fuse Protection

Battery systems can deliver dangerously high short-circuit currents. A dc listed, current-limiting fuse must be used in each ungrounded conductor from the battery in order to limit the current that a battery bank can deliver to within the withstand of the components to be protected per 690.71(C). Current-limiting overcurrent protective devices are marked on the label "Current-Limiting."

### Power Distribution, Splicing, and Terminal Blocks

There are specific requirements and many needs for molded termination products in PV systems. Cooper Bussmann provides these products; visit www.cooperbussmann.com and reference the full line catalog.

### Conductors

PV system conductors are installed in environments that can be harsh on conductors. Ambient temperatures may require derating the conductor ampacity. Also, conductor ampacities based on terminal conductor temperature ratings for all devices with terminations must be considered. For more general information on this subject, see Conductor and Termination Considerations section in this publication.



NDN111- rail mount terminal block.



PLU3- pluggable rail mount sectional terminal block.



NDN3- rail mount terminal block.



Series 14002 barrier terminal block.